

Archeologia e Calcolatori
13, 2002, 259-265

PLAYFUL AGENTS, INEXORABLE PROCESS: ELEMENTS OF A COHERENT THEORY OF ITERATION IN ANTHROPOLOGICAL SIMULATION

This paper is concerned with establishing the basis of a theory of iteration. It makes two basic arguments:

- 1) that iterations must be bound by the rhythm of inexorable physical processes consistent with the human experience of time, and
- 2) that within the limits of that rhythm, agents must be free to make decisions about the use and allocation of time, according to internally held beliefs, and for the achievement of internally held goals and the elaboration of performance.

I present an implementation of a simulation model based on free-form “impulses”, individually controllable by agents, as an alternative to the traditional linear and phase-based simulation models used in Anthropology thus far. In these traditional models, agent activities and external processes are generally resolved in an arbitrary order. As we will see, there are two major and immediate benefits to a more free-form system in which, within the bounds of an iteration, agents can decide the order in which they would like to resolve social interactions, and in which external processes can intervene unpredictably. First, such a free-form system makes it much easier for a simulation to shed elements which traditionally pre-structure at least some of its output. These elements include annual fertility tables and age-based annual survivorship curves. Second, the new system allows the agents a much more naturalistic cognitive relationship with their social and natural environments.

Simulations in Anthropology, from the very classic, such as WOBST’s (1974) paleolithic population simulation, to the recent, like WHITMORE’s (1992) simulation of disease and death in the Mexico Basin and READ’s (1998) simulation of !Kung San demography, have generally taken an *ad hoc* approach to the problem of iteration. There is, in the simulation literature in Anthropology, no systematic discussion of the problem of iteration. Each of the three, excellent, above named models is essentially a population simulation, and each uses a period of one year as an iteration. I hope to show in this paper that there are very good reasons why choice of iteration length is important, and why an arbitrary length of one solar year, or any other arbitrary length, limits the power of simulation models for the solution of anthropological problems. I will use one simulation approach to anthropological problems, Agent Based Simulation, as a background against which to discuss the problem of iteration.

The problem of iteration is essentially the problem of the representation of time in a simulation. A simulation is itself a representation of our understanding of an observed phenomenon.

Human agents, as Charles TAYLOR (1993) argues, are “embodied”. They have a particular perspective on the world around them, and have immediate access to a limited portion of that world. Furthermore, they organise their knowledge of the world in terms of internally held goals and beliefs. Human agents are situated in space, and the information available to them at one location can be seen as a flow, or quantity of information over a given period of time. Human agency is constrained by the access of actors to information. In simulation terms, an agent’s total access to information over a given period of time can be considered broadly equivalent to its perspective on the world. An agent sees the world from one or a set of physical locations over time. The extent of this set of physical locations is limited by time.

Because human agents are situated, an agent based simulation, in order to be useful as a representation of social process, must also situate its agents. Their perspective on their world must be sufficiently like our own to allow hypothesis testing about at least some aspects of human behaviour and organisation. Agents must be nodes through which information flows at a rate which is commensurate with human access to space over time. Agents must exist and behave in a world of human proportions, and they must deal with time-critical imperatives which are consistent with those of human experience.

From a human perspective, time (and therefore access to space) is punctuated by a number of inexorable physical processes, some of which are internal to humans (for example the female reproductive cycles, both long term and short term), others external (for example, seasonal regularity in plant growth). The flow of information which constrains and channels agent decision-making and action must be measured against at least one of these processes.

Information is a crucial raw material of human agency. Information is not abstract. It is concrete and measurable, and must be within reach of an agent to be relevant. Its flow must be measured and understood in terms of the inexorable processes which punctuate and organise the human experience of time and therefore of space (since without time, there is no change of location).

The central problem of iteration in anthropological simulation therefore lies in the selection of the particular inexorable process whose rhythm will organise the agent’s experience of time and consequently its construction of performance. The agent’s experience of time limits its access to information, and therefore constrains and channels its decision making and, actions.

Within the bounds of the selected inexorable process, between the beats of this systemic rhythm, agents must be free to engage in the constant negotiation, or play, which characterises human social processes. This will become clear if we consider a particular ethnographic example. Here I have selected the timing of mortuary feasts in Highland New Guinea, but a host of other examples would do just as well.

Highland New Guinea men compete for the prestige rewards of holding important feasts. The holding of a feast depends on the timely concentration in time and space of a large amount of specific resources. The traditional phase-based simulation is inadequate for the representation of such a social dynamic.

In the phase-based model, operations are resolved in a particular, often arbitrary order. For example, a phase based simulation might, within an iteration, first check all agents for mortality, then check all agents for reproduction, and finally for marriage. The relationship between marriage, which often involves the investment of bride-price, and the timing of mortuary feasts is especially critical. From a human agent's perspective, a death can occur at any time, and so can a relationship between two young people. The social impact of such events is immediate. The timing of the social recognition, or the social construction of these events, however, is highly negotiable. The scheduling of any given feast might impact the scheduling of a number of other feasts. Indeed, the mere possibility that a certain feast might go ahead could be sufficient to severely affect decision-making by a number of agents in a range of contexts.

In order to accurately reflect their social counterparts in the agent's experience of its world, simulated marriages and mortuary feasts must be amenable to scheduling. In other words, it is important that they can happen at any time *within* an iteration, in relation to any other type of event, for example a serious illness. It is also important that feasts have the ability to mutually disturb each other's timing. Uncertainty about scheduling is one of the key attributes of this and many other social processes. The traditional linear phase based system, while it can incorporate some uncertainty, tends to minimize it, whereas a more free-form impulse system allows uncertainty related to event scheduling to exert a greater influence on agent decision-making.

I will now outline a simulation model which meets both specifications laid down above: it organises the agent's experience of time in terms which are humanly relevant and commensurate with the human experience of time and space, and it allows the agents free rein to negotiate the timing of individual events in terms of internally held goals.

The C++ source code on which the following discussion is based is available from the author. In order to maintain an anthropological focus, the

text will be free of technical detail, and the emphasis will be on conceptual and modeling problems.

The iteration in this particular population model is constructed around the short-term female reproductive cycle. Each iteration therefore represents approximately 28 days. The first noticeable benefit of this approach is that it allows the modeling of reproduction to shed its dependence on annual fertility tables and adopt a fecundity based model. The odds of conception for any one mating event can be kept constant for a female agent of a given age, and the probability of reproduction therefore becomes dependent on the frequency and timing of the female agent's mating activity. This allows for realistic fertility variations as a function of mating behaviour frequency (and thus contextual opportunity in the form of access to male sexual resources) and the variations of individual agent fecundity over time. An important source of artificial structure (imposed annual fertility rates) is thus removed from the model, allowing the simulation's results to emerge more freely, especially in the very long term. Long-term variations in access to reproductive partners can now have their full effect on fertility rates. This also opens the door to a much closer modeling of environmental and social factors affecting fecundity on an individual agent level.

Before I can discuss what the agents do and why, I must describe the agents themselves and the way in which they perceive their surroundings. In this agent interactional module of the simulation, agents are primarily aware of other agents and of their own relationships to them. They are only very dimly aware of their physical environment, knowing only their location in an abstract two-dimensional plane. The agent's awareness of, and interactions with, a much more complex and comprehensive physical reality has been developed in another module of the simulation (COSTOPOULOS 1999, 2001). The two modules are still separate but the ground-work for their integration is underway. Still, mere awareness of "this place" as opposed to "another place", nothing more than Cartesian coordinates in the agent cognitive system, is enough to embody the agents in a certain sense. They have immediate access to other agents only insofar as they are sufficiently near each other.

At the heart of the Agent social cognition system is a list of constantly evolving agent priorities and a similarly dynamic list of relationships with other agents.

The priorities vary in urgency and the relationships vary in intensity, each according to its own specific time dependent function. Some of the agent priorities are in the form of drives, for example the mating priority. These increase in urgency over time unless met. Other priorities are the result of action by other agents. For example, offspring have a care priority which they communicate to nearby adult agents. The signal's strength falls off as the juvenile agent ages. The signal causes the creation of a reciprocal

care priority of the same urgency in the adult agent, thereby potentially modifying and rearranging the adult agent's internally determined list of priorities. The list of priorities forms the receptor component of the agent's social cognition system. It creates the criteria which the agent will use in order to organise and make sense of the social reality which surrounds it.

Having acquired goals and expectations, in the form of a ranking of priorities, the agent is now ready to examine the social world around it and to make use of it. Agents now determine the portion of their time budget which they are going to dedicate to the pursuit of their top priority.

Iterations, rather than being broken down into phases given over to particular activities or processes, are divided into impulses, each of which can be used by one agent to perform one action. The number of impulses available in any one iteration is proportional to the number of agents in a population. The order in which agents perform their activities is determined by a bidding process. Agents have a limited time budget and they mobilise part of it to try to take control of a particular impulse. Each agent bids a portion of its time budget equivalent to the urgency of the top priority identified. I am currently also developing the agents' ability to negotiate the mobilisation of part of the time budget of other agents with which they already have relationships or can seek to establish them.

Once an agent has obtained control of an impulse, it takes an action. Any action taken by an agent can in turn affect other agents and influence their ranking of priorities. Before the next impulse is resolved, all agents re-evaluate their priorities in the light of the previous impulse's events, and the bidding process begins anew. When the maximum number of impulses is reached, the iteration ends.

Events which are independent of agent planning can also take over an iteration. At the moment, there are three events in the simulation model which are independent of agent control, can intervene unpredictably, and can have far reaching consequences on the relationship and priority systems (i.e. social cognitive systems) of some or all agents in a population. Births, episodes of illness, and death can all occur at any time during an iteration. I will examine all three events in turn, and discuss the mechanism of their timing and their consequences.

At the start of each iteration during which it is pregnant, a female agent determines whether there will be a termination of pregnancy. The probability of termination increases with each iteration, and the probability of live birth increases. If the pregnancy is terminated too early, the odds of live birth are very low to none. If there is a normal termination of the pregnancy, the female agent is randomly assigned an impulse number during which it will automatically take over and give birth. The births are therefore scheduled independently of other types of events and can intervene at any moment

during an iteration. Of course, births are predictable within a narrow range, but their exact timing must remain uncertain. It is easy to see how a birth can radically affect the priority and even relationship arrays of all agents within a local group, thereby completely modifying their plans and behaviour.

In this simulation model, episodes of illness are the result of the interaction between agents and an overall threat environment. The threat environment is made up of non-human agents which represent pathogens, potentially self-destructive behaviours and other threats. Each threat can have preferences and tolerances for age and sex of potential victims. For example, males between the ages of 8 and 12 might be more likely than others to fall off tree limbs, etc. Each threat has a time budget which it can use to locate and attack victims in the population which correspond to its preferred profile. Threats also bid for control of iterations. If a threat locates a suitable agent and attacks it, a range of abstract values, representing the threat's characteristics is compared to a similar range of values for the agent. The result of the attacks varies from no ill effect, to a decline of the agent's health status, to immediate death. Illness and death are therefore both scheduled independently of agent activities and planning, and are the result of opportunistic activity on the part of the non-human agents which make up the threat environment. Note that this simple mechanism leaves completely open the question of agents' perception of the threats and interpretation of these uncontrollable events.

Deaths can occur at any point during the iteration (i.e. during any given impulse within an iteration). A death forces agents who's relationship lists included the dead agent to rearrange their relationship lists, and may also result in significant shifts in priority lists far beyond the deceased agent's local group.

The system of threat environment, emphasizing the relationship between agent and threat, as well as the incidence of opportunities for threats to affect agents, introduces a more selectively oriented morbidity system into anthropological simulation. Instead of relying purely on age based survivorship curves, this system takes into account the local pathogen environment, agent behaviour, as well as the characteristics of individual threats and agents. Survivorship curves are then allowed to emerge from the long-term interaction between population and threat environment. Any change in either population or threat environment can lead to a modification of the survivorship curve for a local group or for a population as a whole.

A free-form impulse based iteration, built around a time-critical physical process, during which agents can order priorities, evaluate urgency, and negotiate action, allows population models to shed some of the elements which traditionally pre-structured at least some of anthropological simulation's long-term output. When combined with an agent design which em-

phasizes physical situatedness and social cognition mechanisms, the impulse based iteration allows agents a more recognisably human-like experience of time and social environment. This makes them more useful for the investigation of social process.

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ABSTRACT

This paper presents an alternative to the purely sequential and arbitrary resolution of events in agent-based simulation for Anthropology. It is argued that an alternative system in which agents constantly evaluate their priorities in the light of the actions of other agents provides for more realistic social interaction and allows for the emergence of social-like processes in a computer agent population. A number of other problems, such as the production of survivorship curves from a threat environment, are also discussed.

